# Compound Interest - Dealing with Two Decades of Technical Debt in Embedded Linux

Bartosz Golaszewski

Embedded Open Source Summit 2024, Seattle, WA

Linaro

# About

- Linux kernel developer for the Qualcomm Landing Team at Linaro
- 15 years of embedded linux experience
- Maintainer of the GPIO subsystem
- Author and maintainer of libgpiod
- Open-source contributor to many other projects
- Interested in complex software architecture

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**Linaro has enabled trust, quality and collaboration since 2010**

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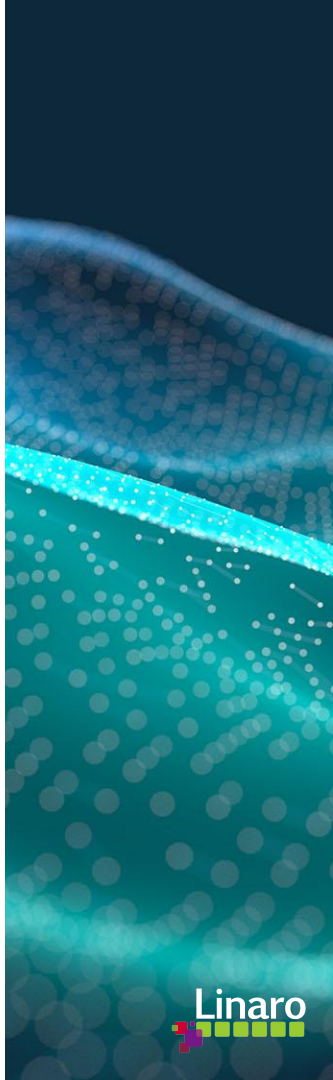
# What is “technical debt” in software?



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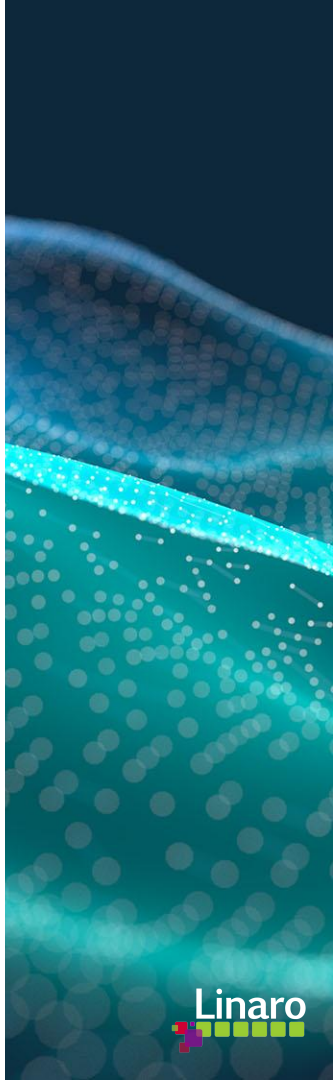

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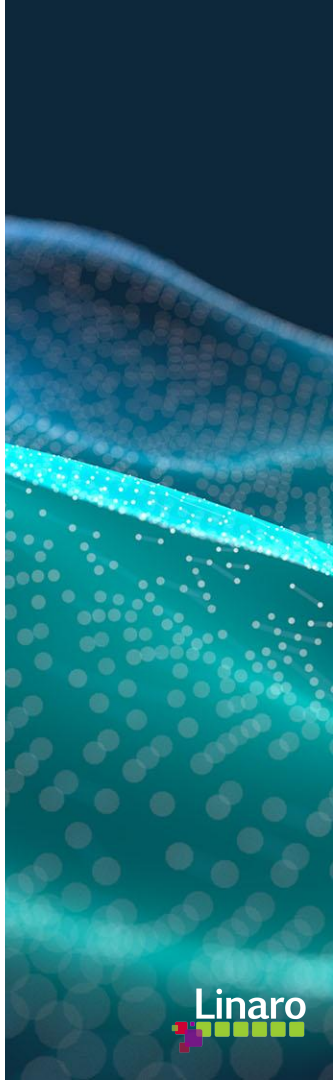

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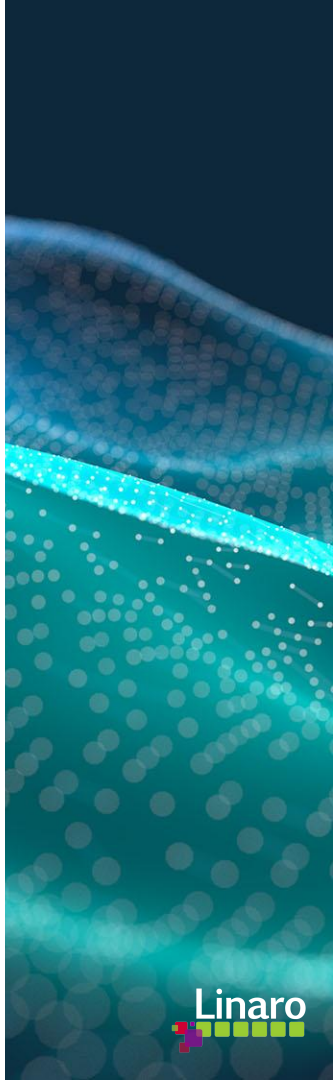

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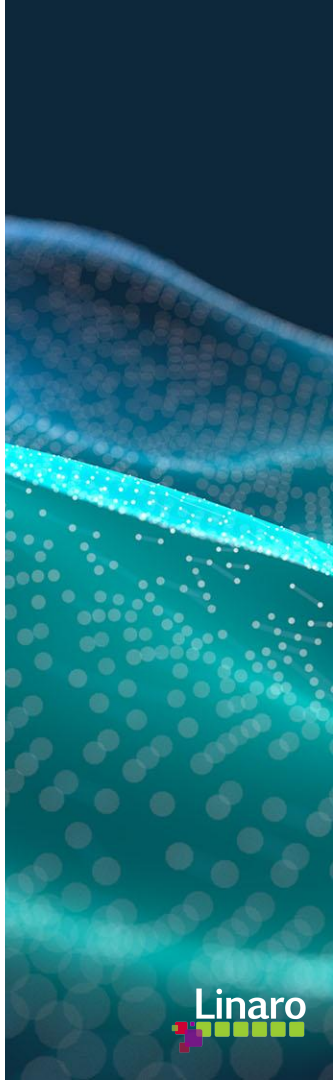

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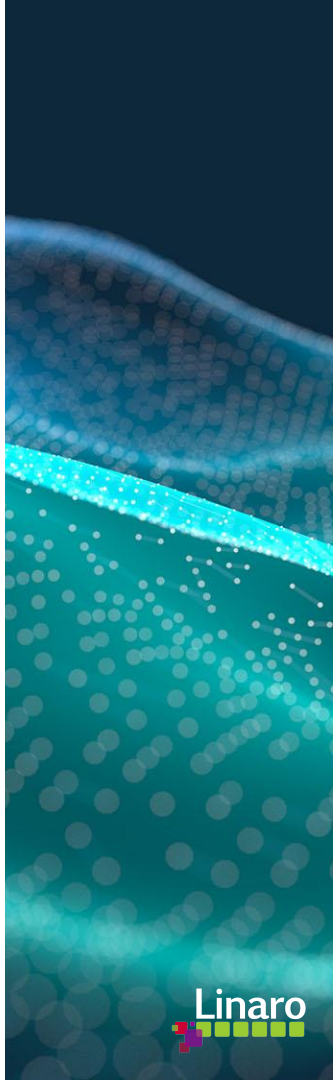
- Worst kind of technical debt in programming is not the implementation details, it’s data structures and most importantly: programming interfaces!



# So you want to start working on a piece of software?

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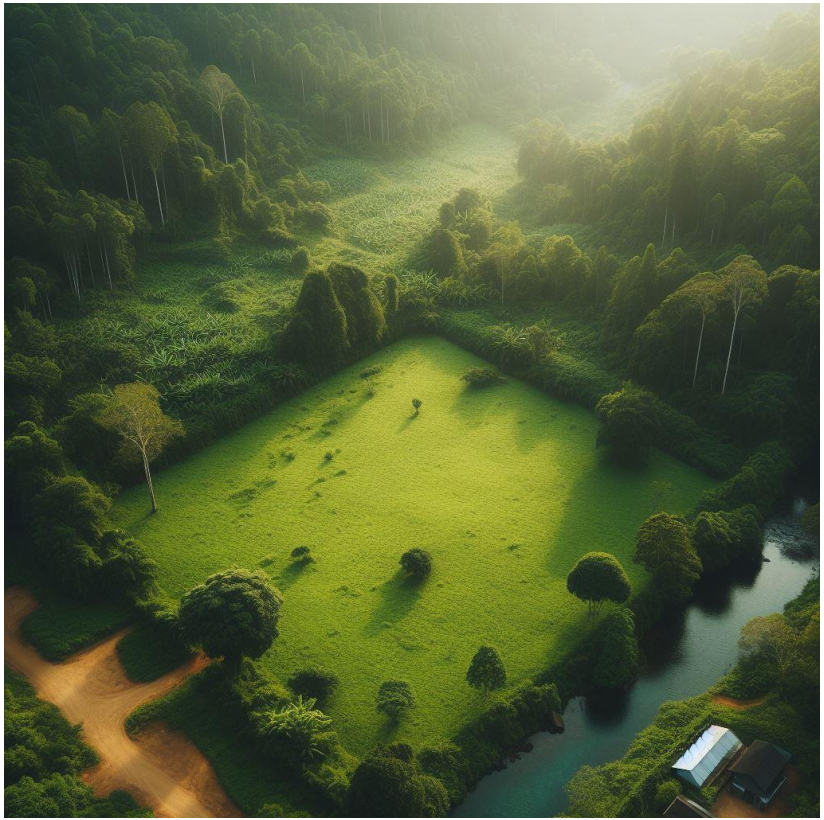
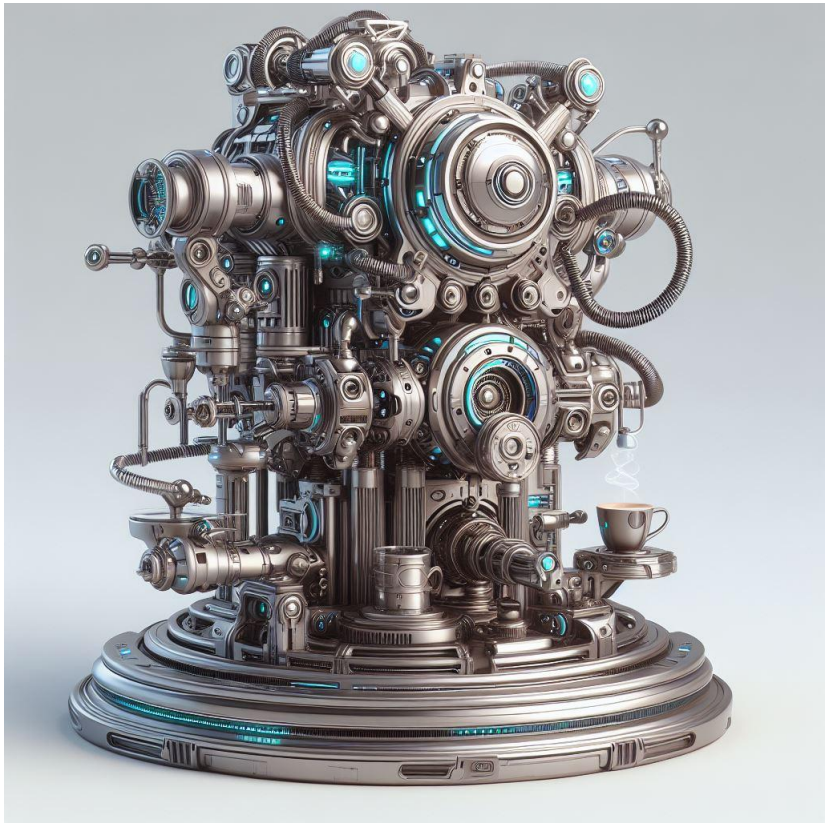
# Case 1: Greenfield development



# Case 2: Well-oiled machinery



# Case 3: Ducty McTapeface

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It works but at what cost...

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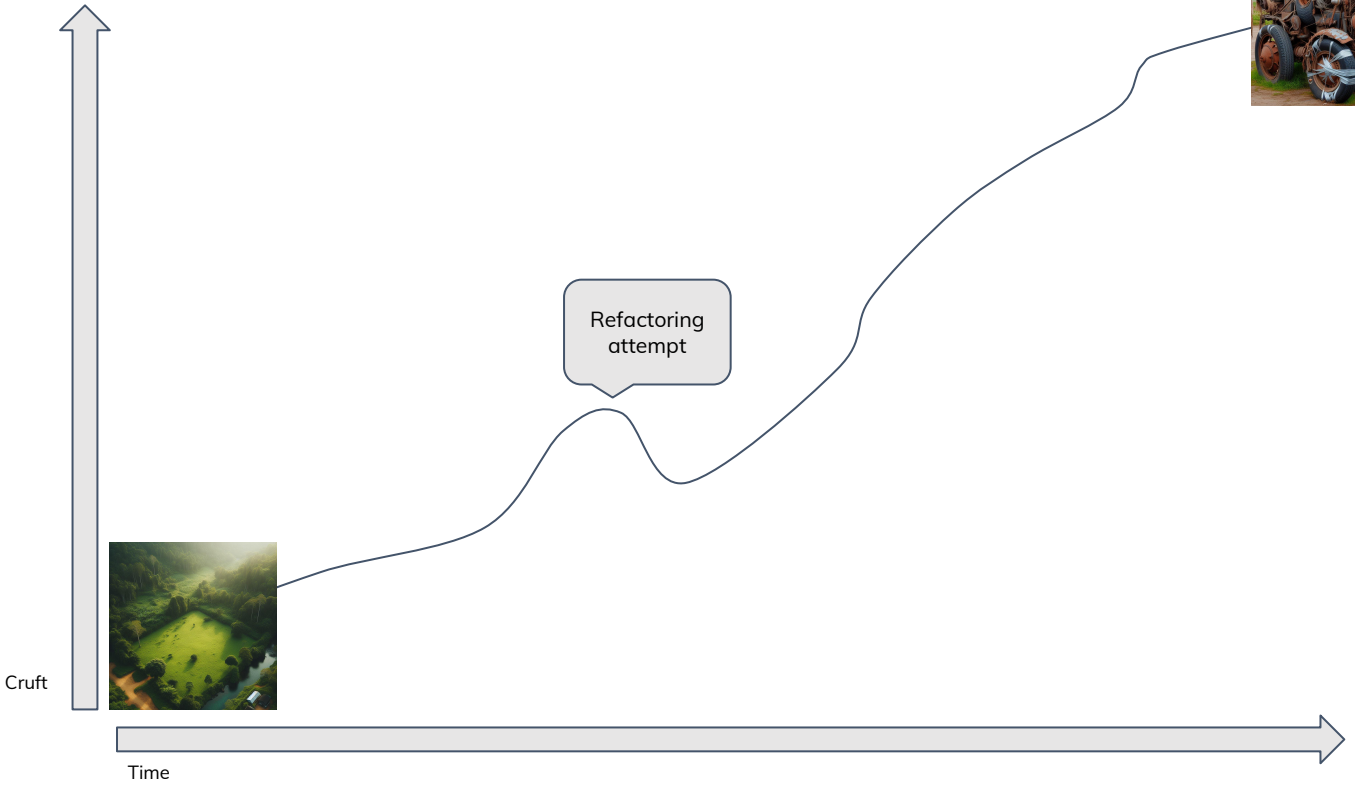

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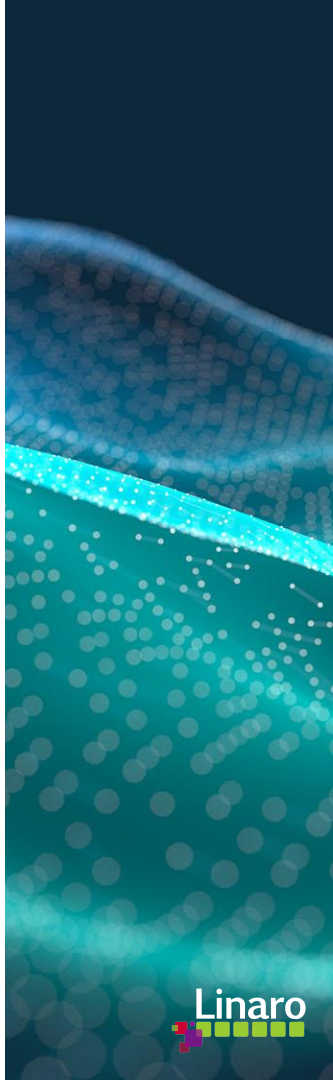

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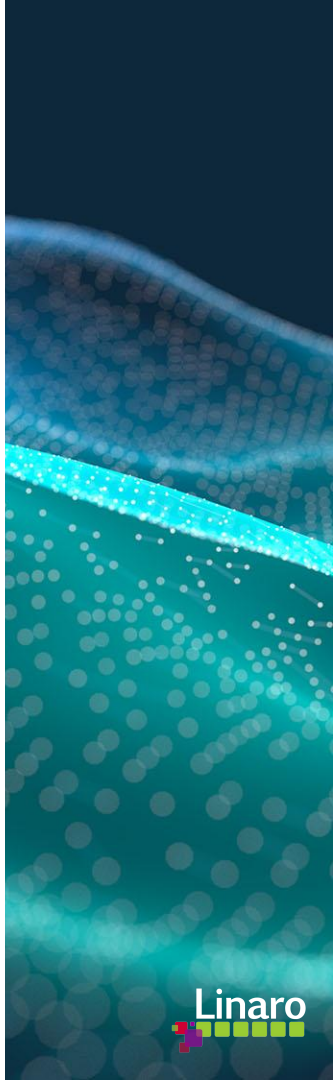
  - Use-cases two years from now may be different
  - Users request more and more new features (often valid ones!)
  - Sometimes one just doesn't know what they don't know



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  - Old use-cases need to be supported
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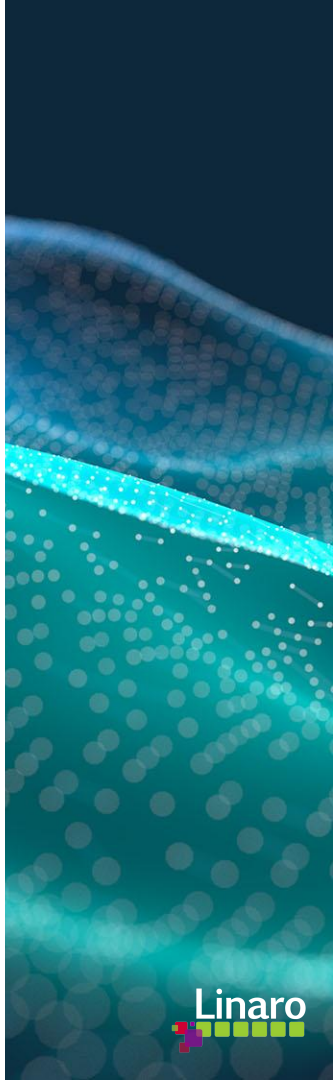
  - Even the kernel has some sort of in-kernel API stability: modifying an interface used in 100s of places is complex
    - Not to mention the user-space ABI stability



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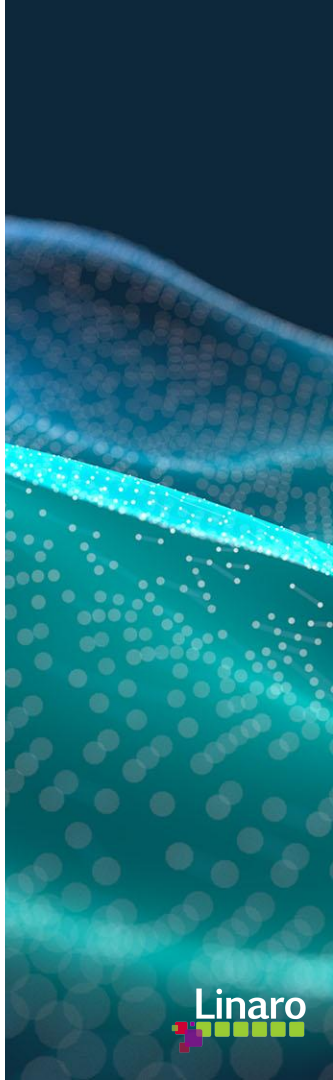
- Lax maintenance
  - Kernel maintainers are often grumpy for a reason
    - Best way to deal with technical debt is to never allow it in the first place
  - Business priorities take over



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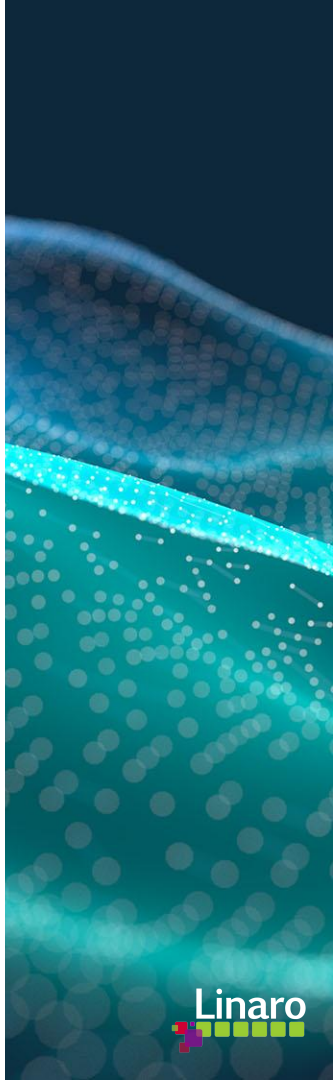

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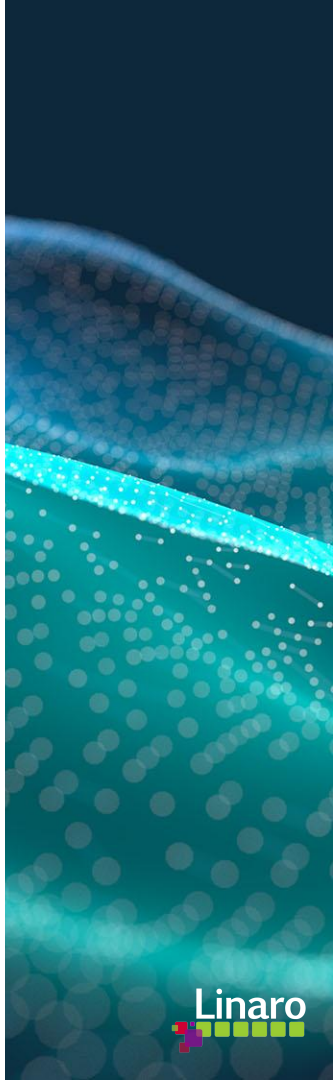

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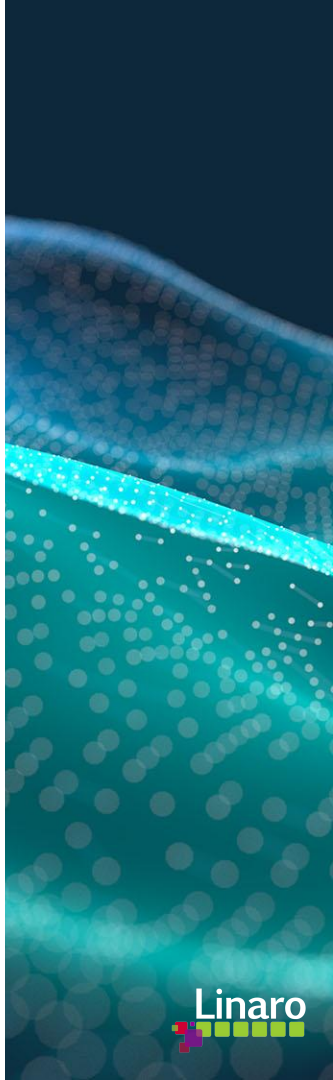

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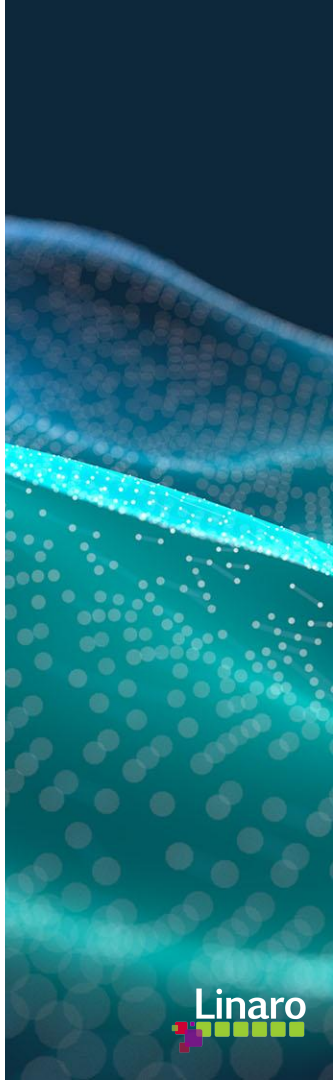
- Lack of a good deprecation mechanism
  - Not possible to always catch people using interfaces documented as deprecated without enforcing it through warnings



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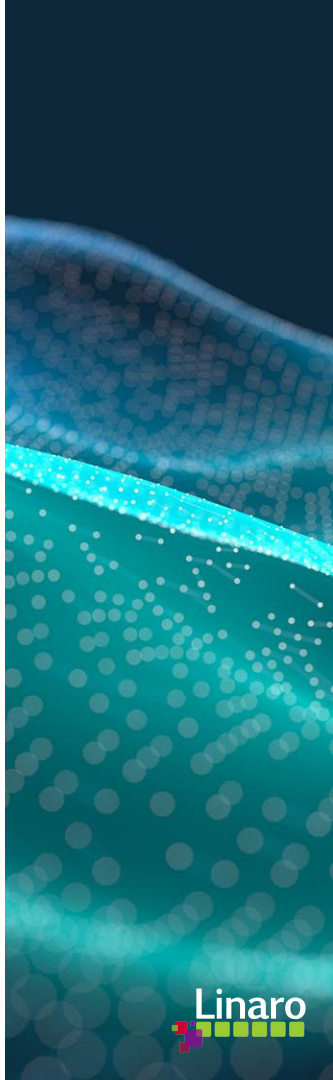

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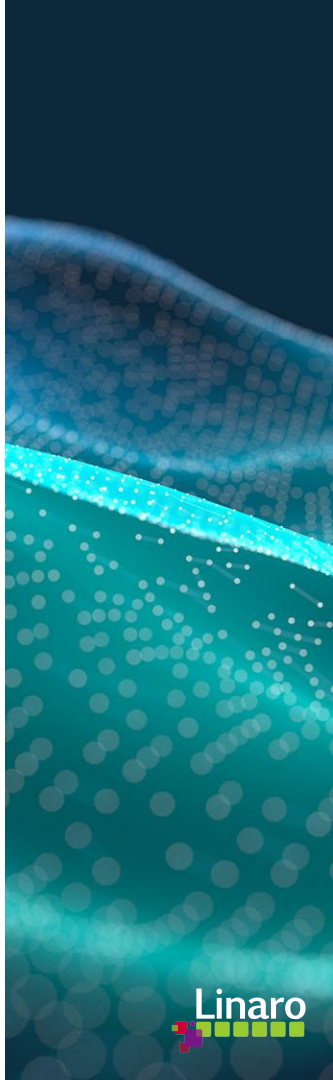

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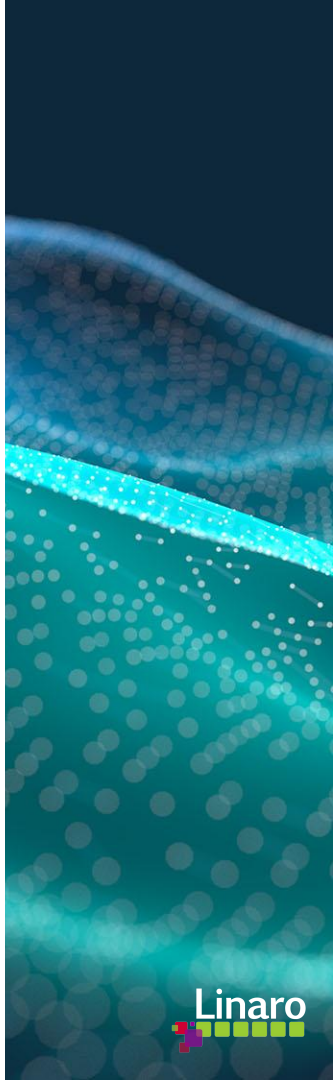

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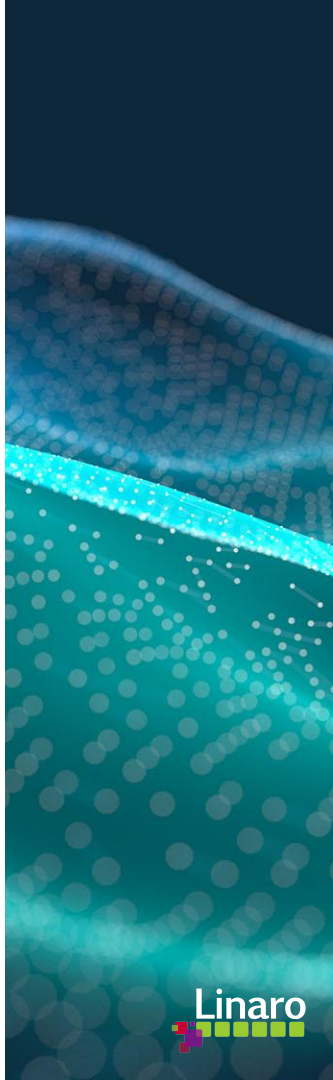

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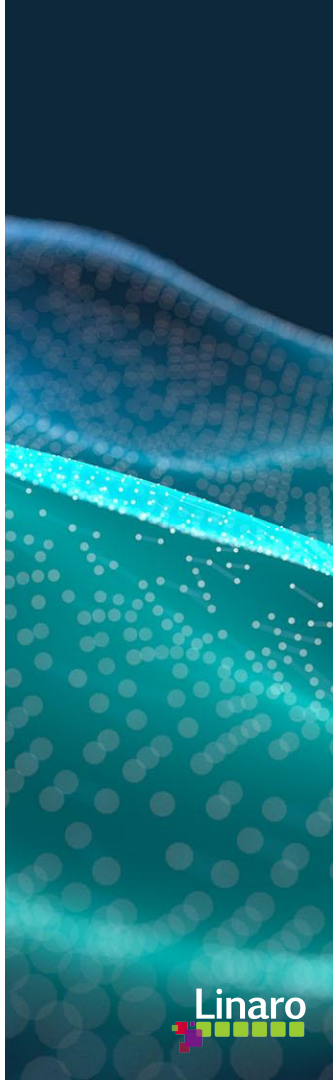

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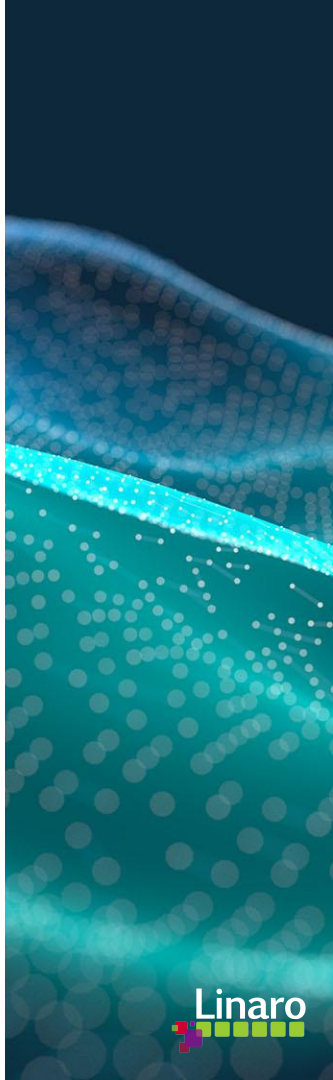

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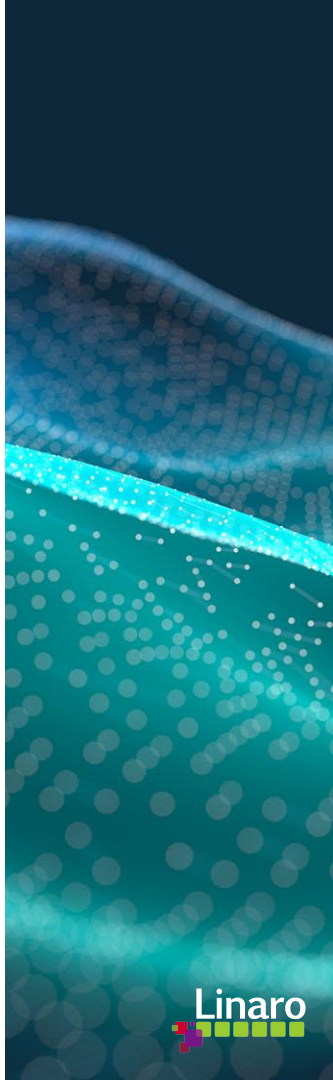

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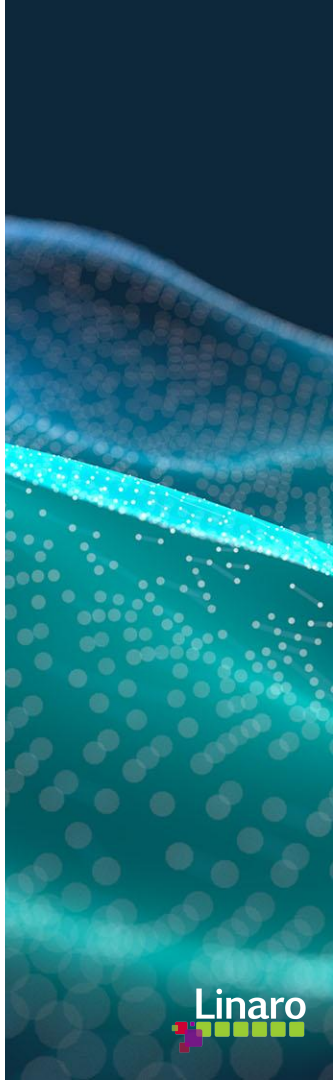

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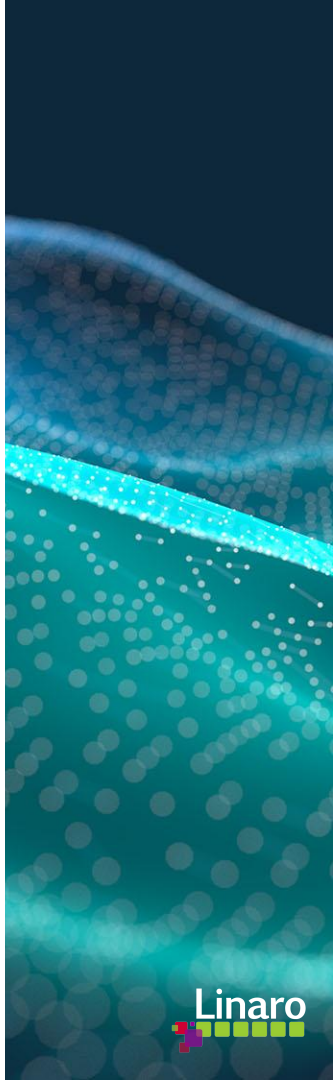
- Over the years accrued a significant amount of technical debt



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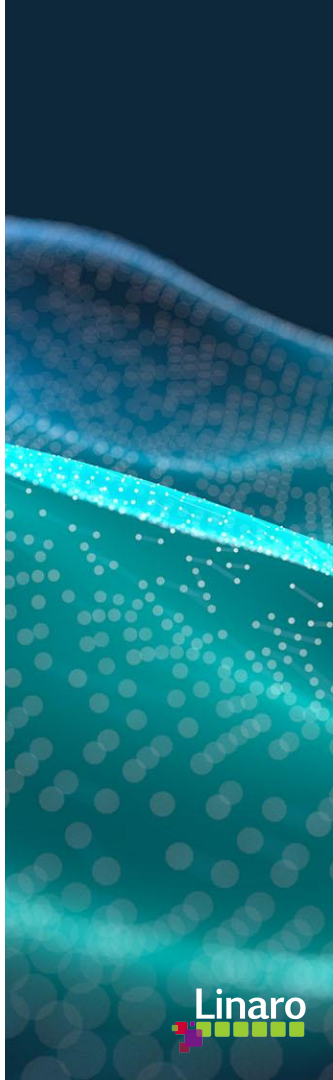

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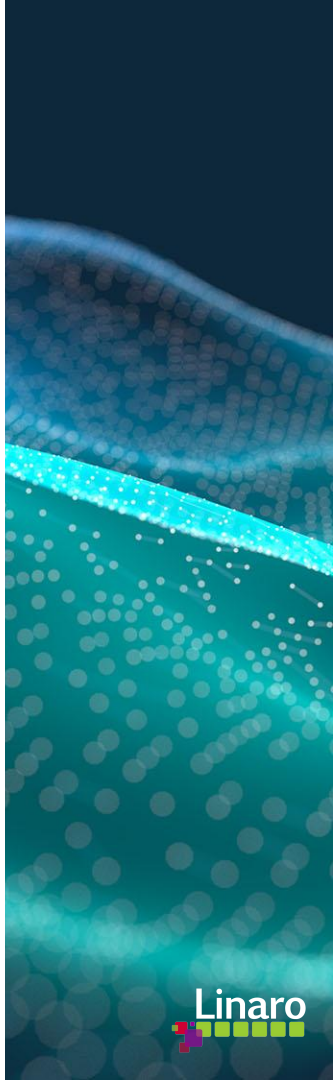

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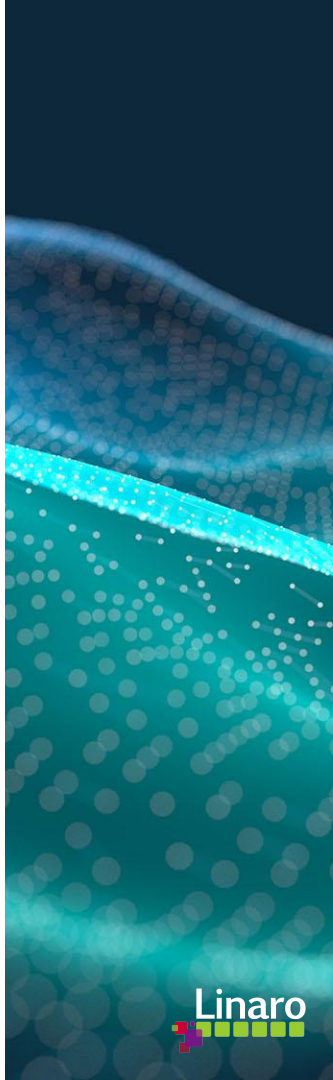

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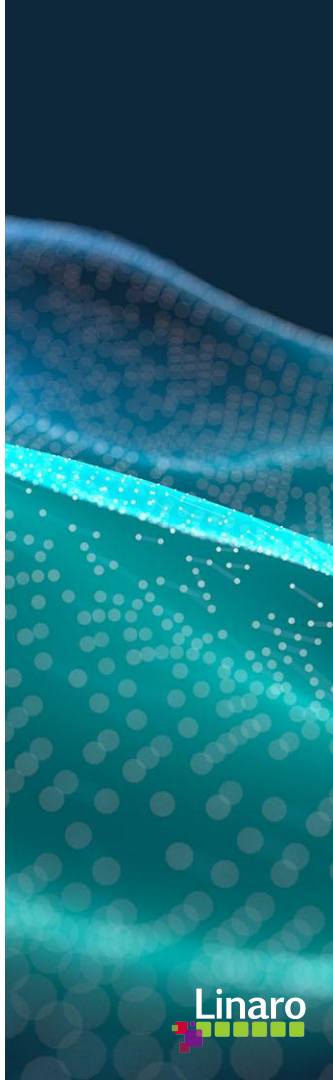
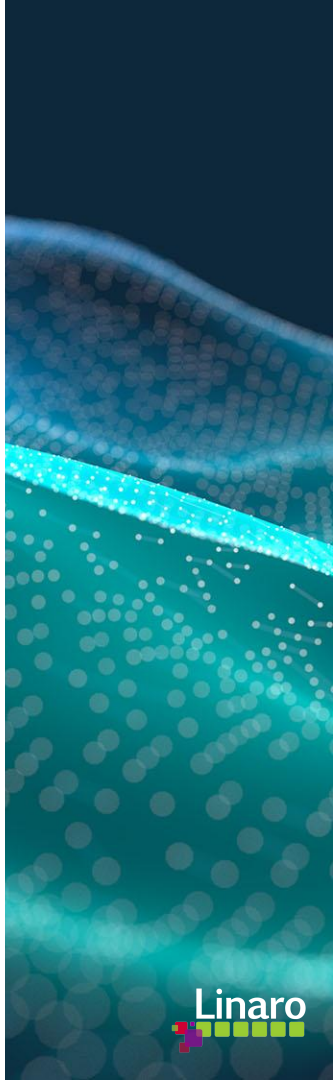
  - We still have GPIO drivers in `arch/` that don’t use the driver model and are only barely duct taped to the GPIO framework



# GPIO global numberspace



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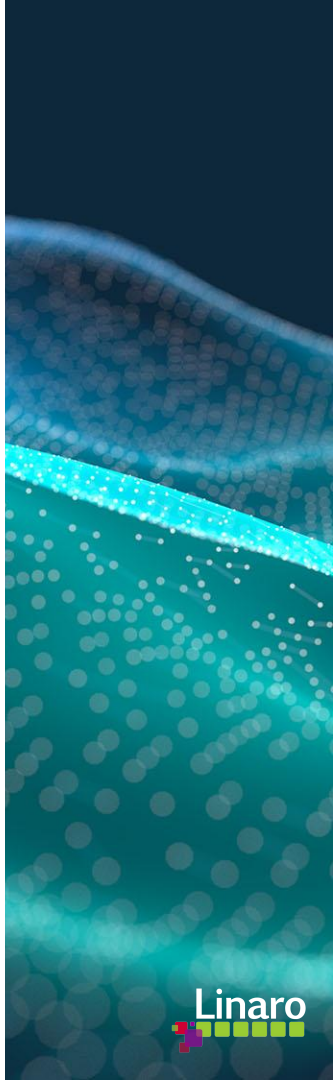

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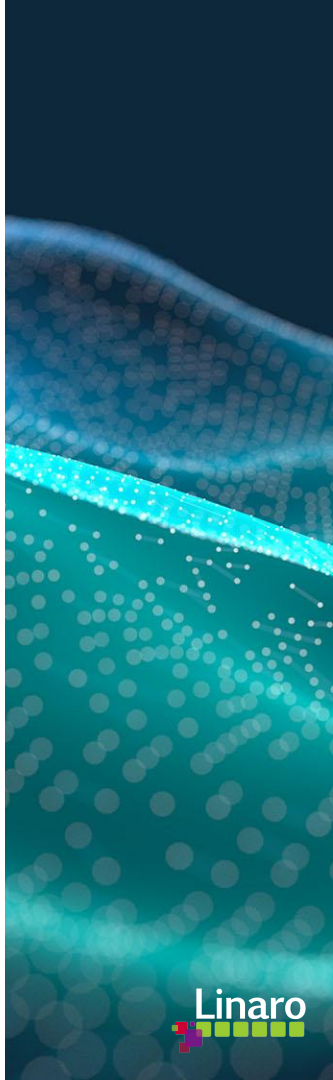

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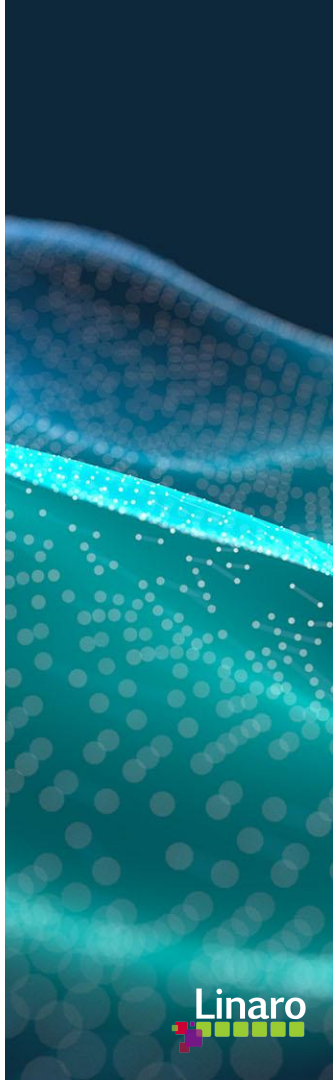
- Consumers get numbers assigned, request them and use them
  - Nothing stops a rogue driver from requesting an arbitrarily hard-coded GPIO number



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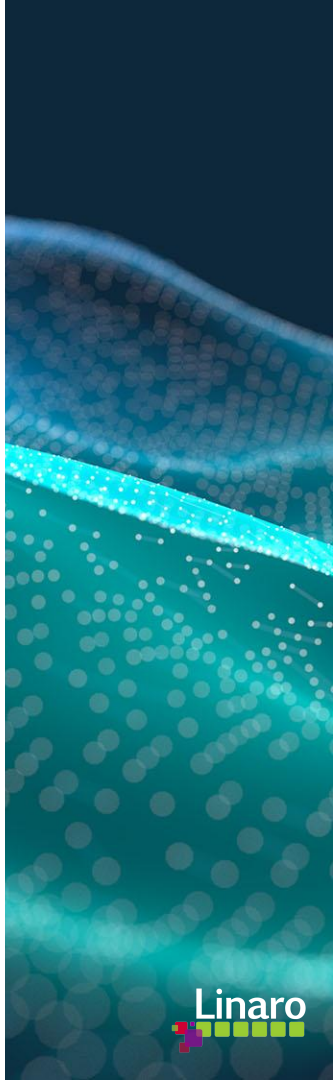

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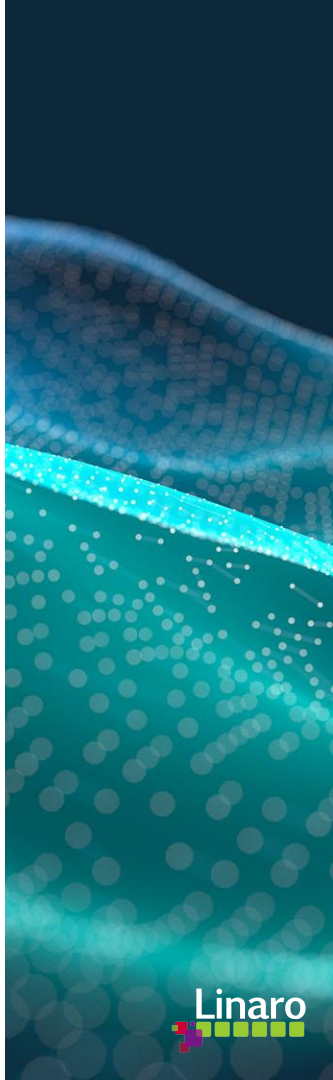

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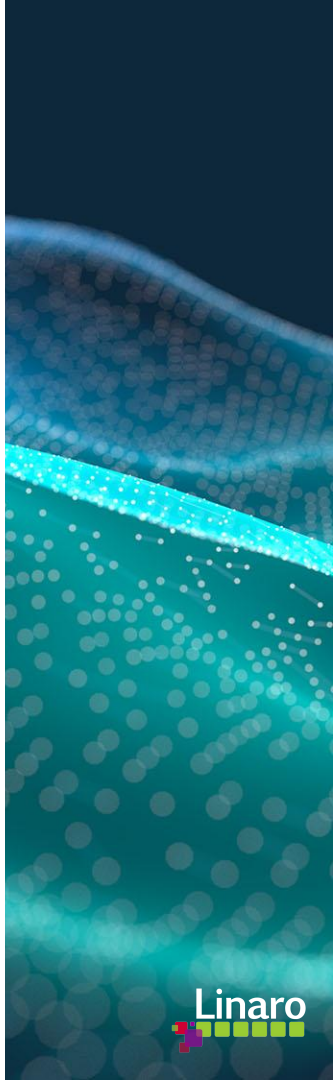

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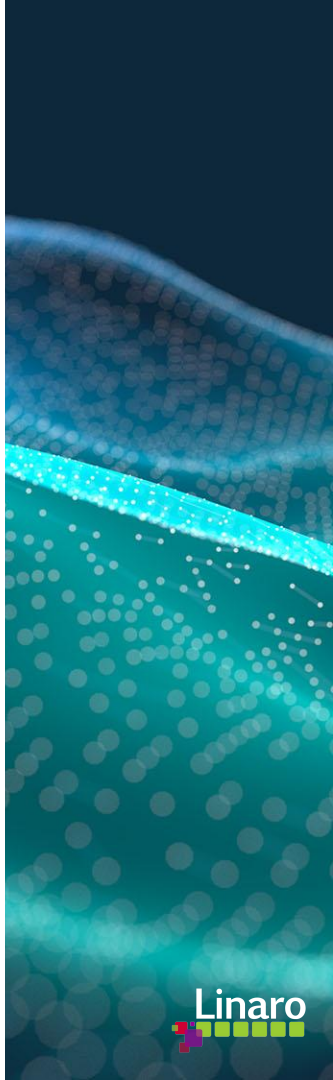
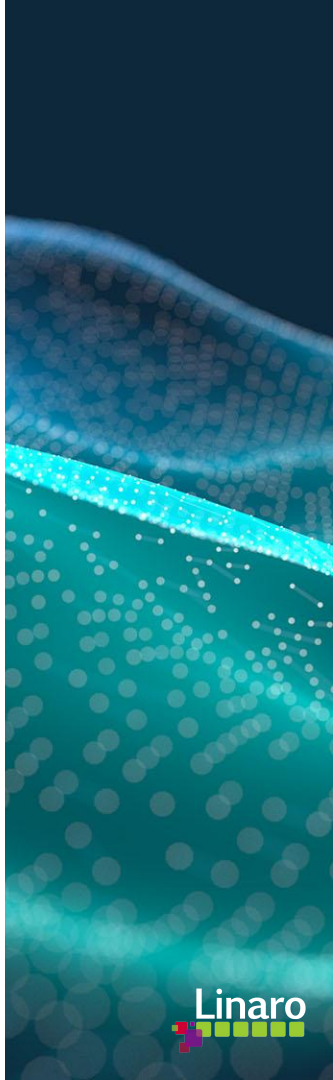
- Technical debt strikes back:
  - Internally GPIOLIB still uses the global numberspace and has a whole glue layer between the two interfaces



# GPIO numberspace removal



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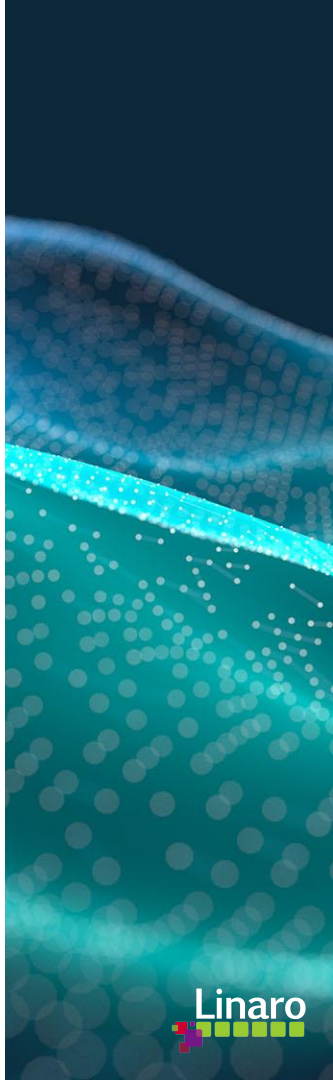

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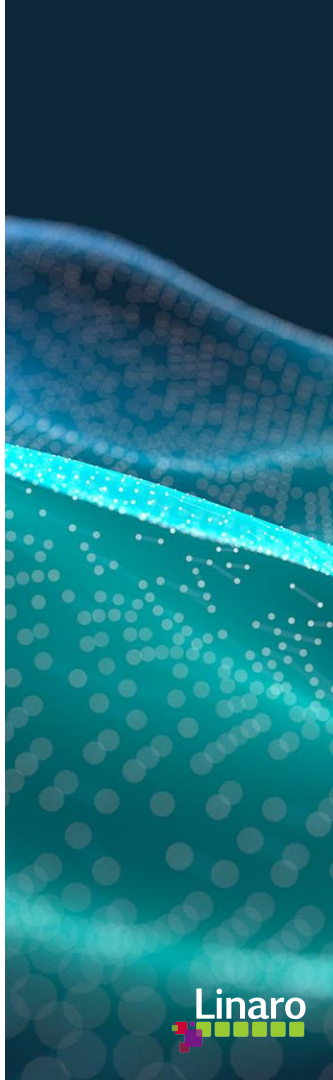
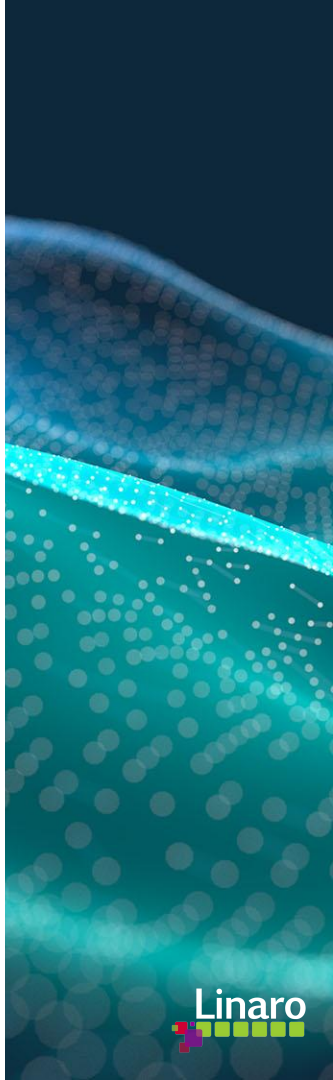
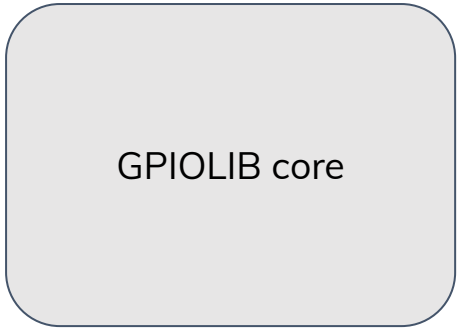


# GPIO numberspace removal

- Work has been ongoing for years
  - Converting users one at a time
- We cannot remove the old interface until we convert all users to the new one
- Even once we convert all in-kernel users, we'll still be left with user-space programs relying on the numbers exported over sysfs
  - Unlike kernel drivers, we cannot enforce the migration of user-space to the descriptor bases uAPI



# Serialization in GPIOLIB



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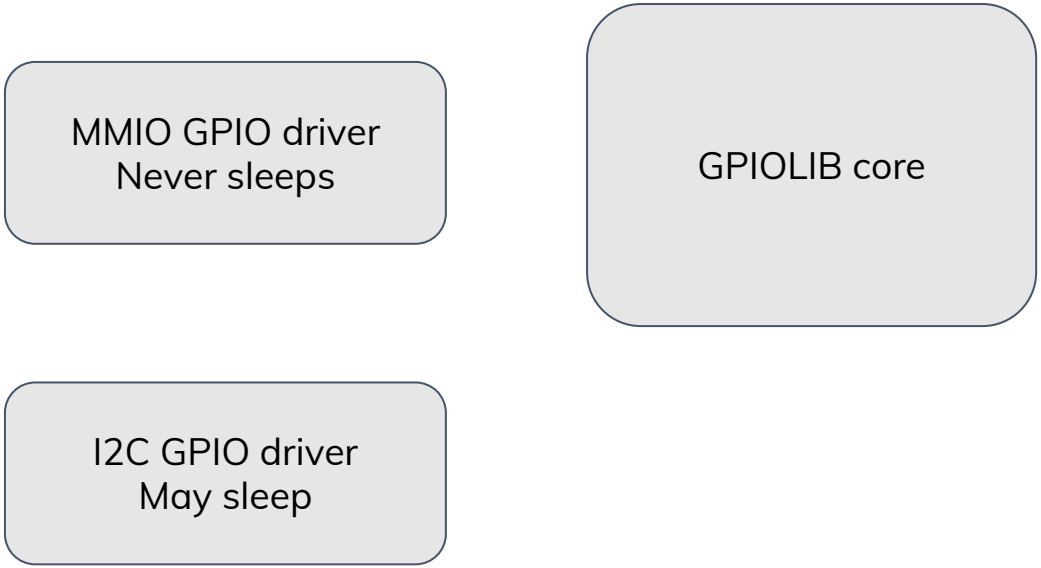


# Serialization in GPIOLIB

MMIO GPIO driver
Never sleeps

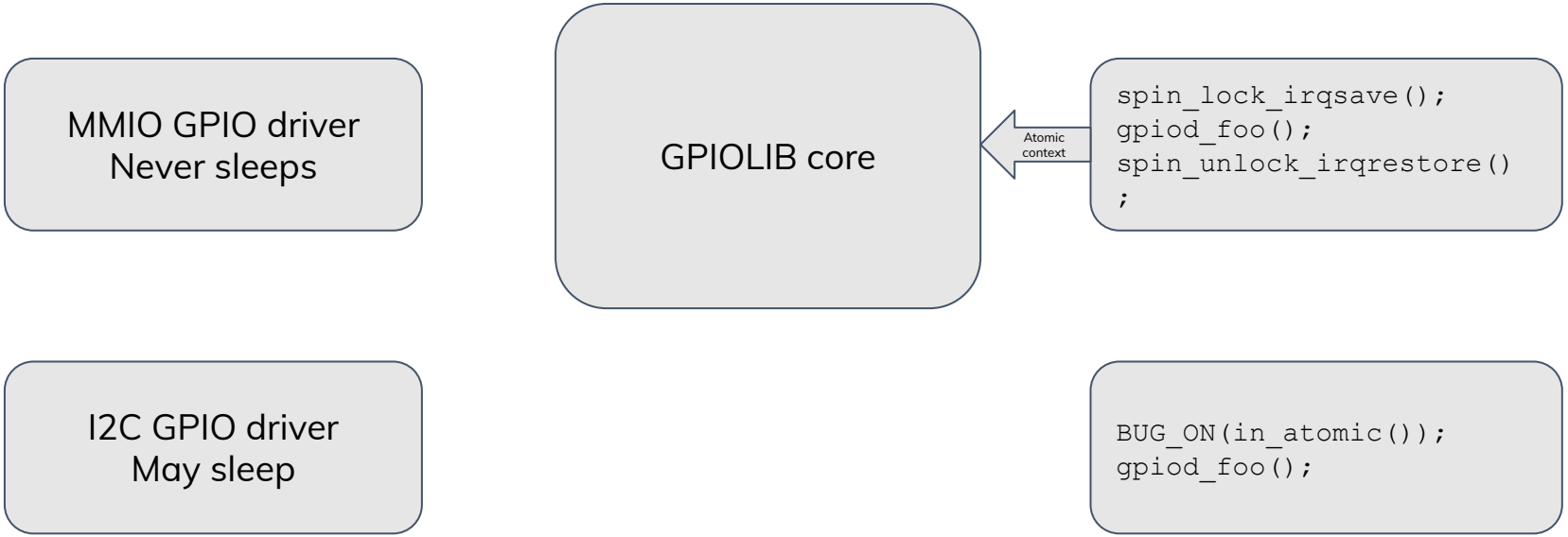
GPIOLIB core

```
spin_lock_irqsave();
gpiod_foo();
spin_unlock_irqrestore()
;
```

I2C GPIO driver
May sleep

```
BUG_ON(in_atomic());
gpiod_foo();
```

# Serialization in GPIOLIB



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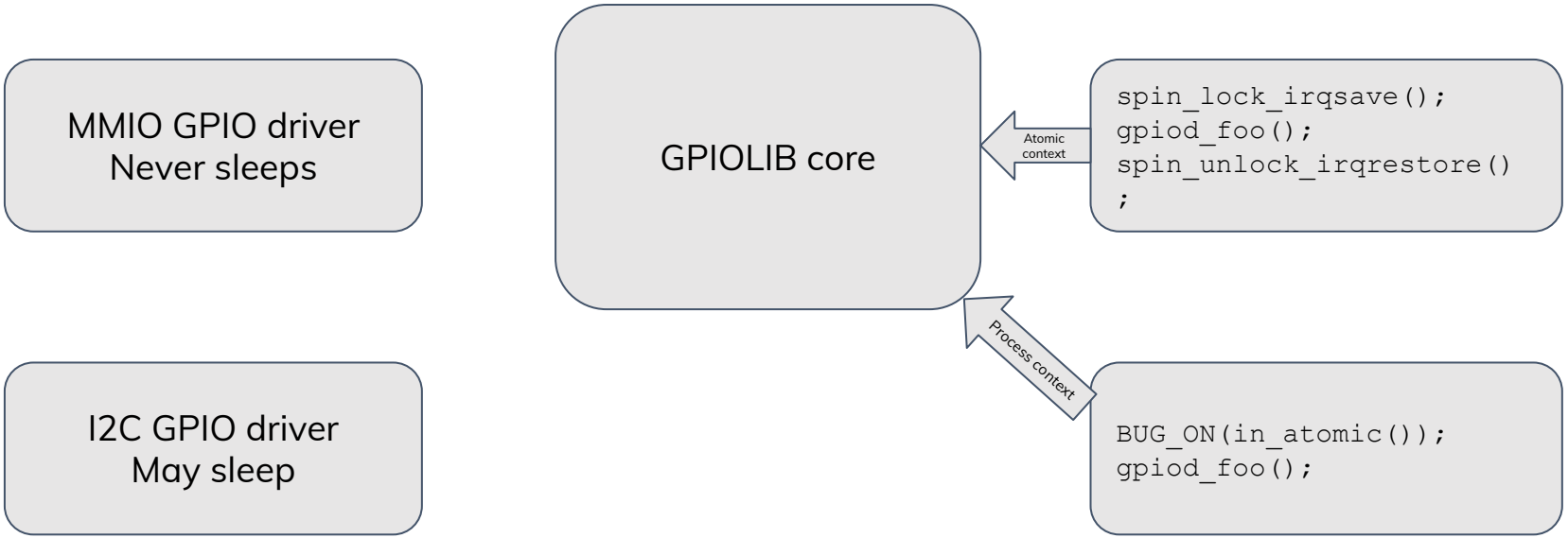


Linaro

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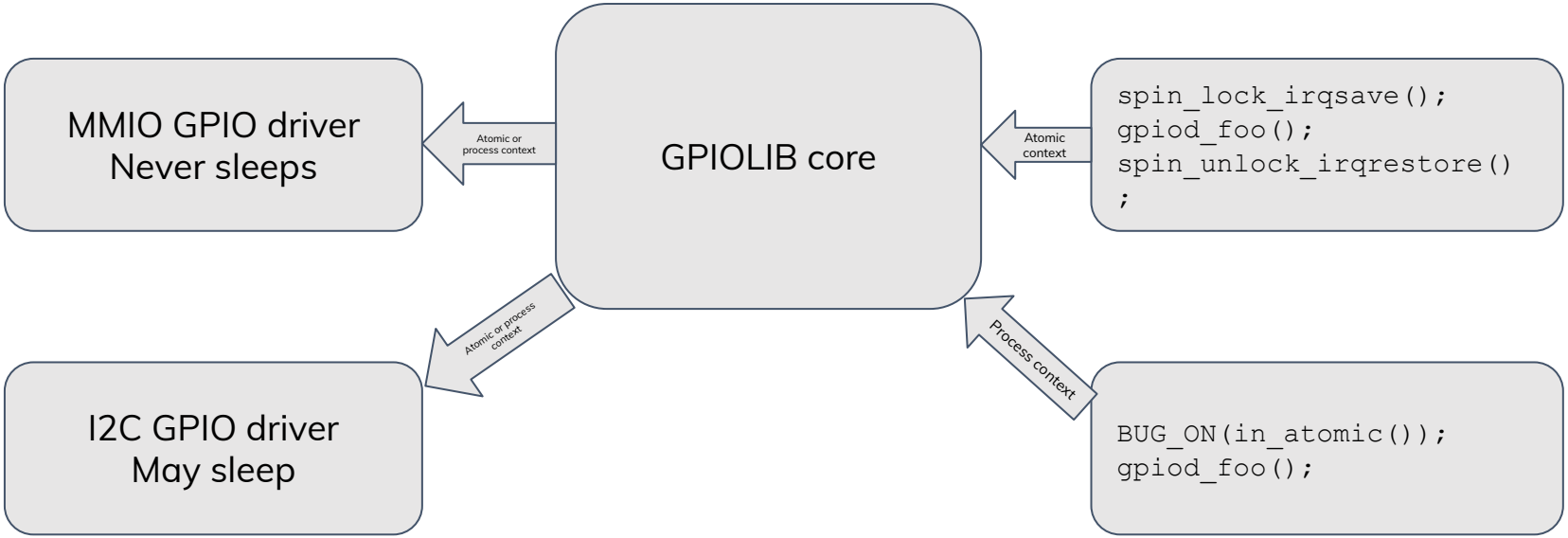


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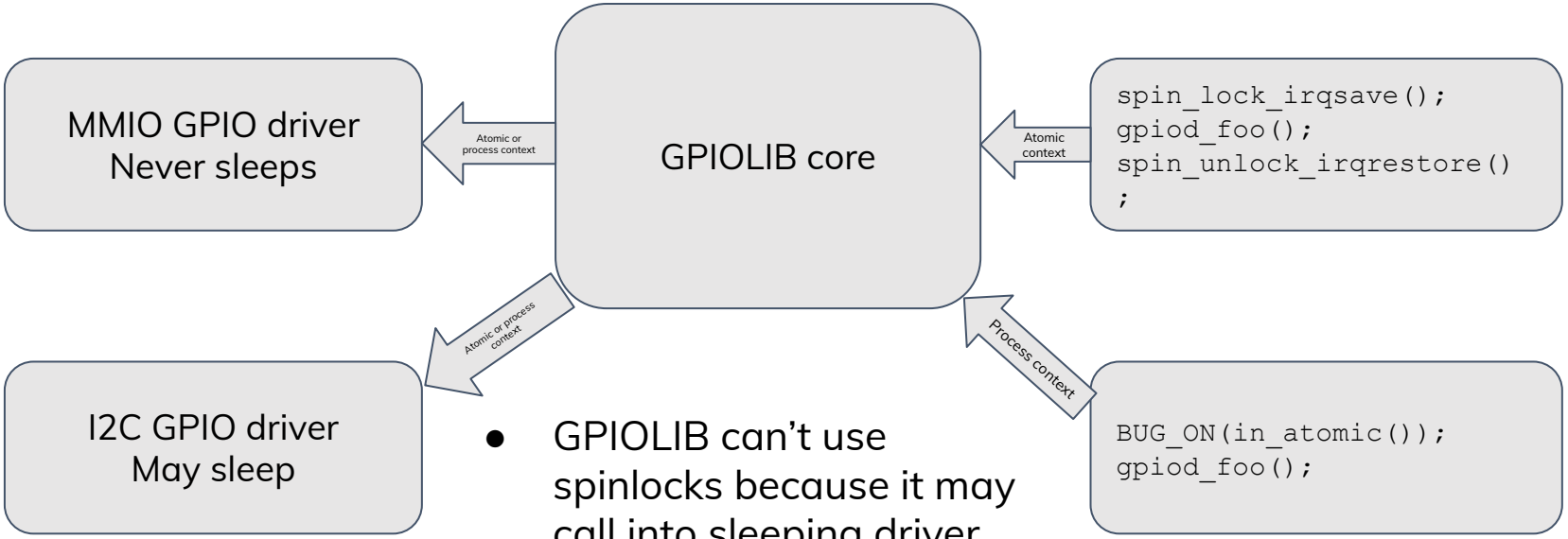
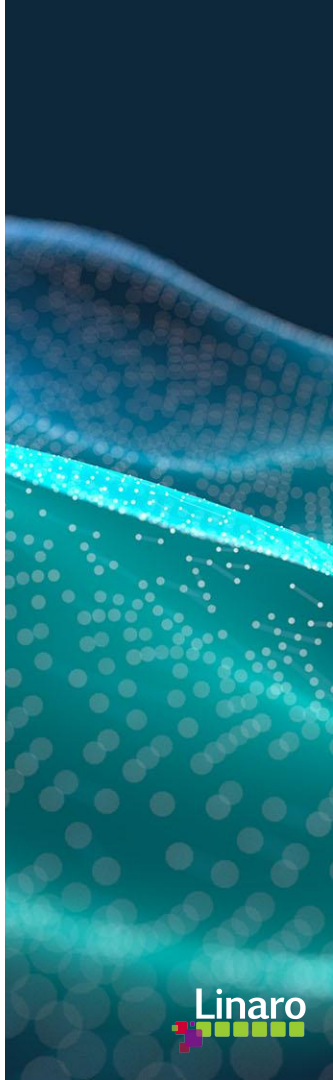



- GPIOLIB can't use spinlocks because it may call into sleeping driver callbacks
- Can't use mutexes either because it may be called from atomic context

# Serialization in GPIOLIB

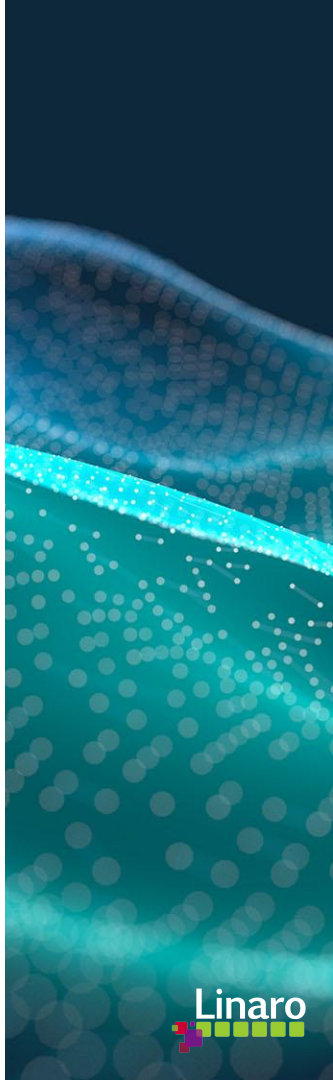
- Spinlocks would be used but badly:

```
spin_lock_irqsave();
do_atomic_stuff();
spin_unlock_irqrestore();
do_sleeping_stuff();
spin_lock_irqsave();
// Don't check state
do_atomic_stuff_again();
spin_unlock_irqrestore();
```



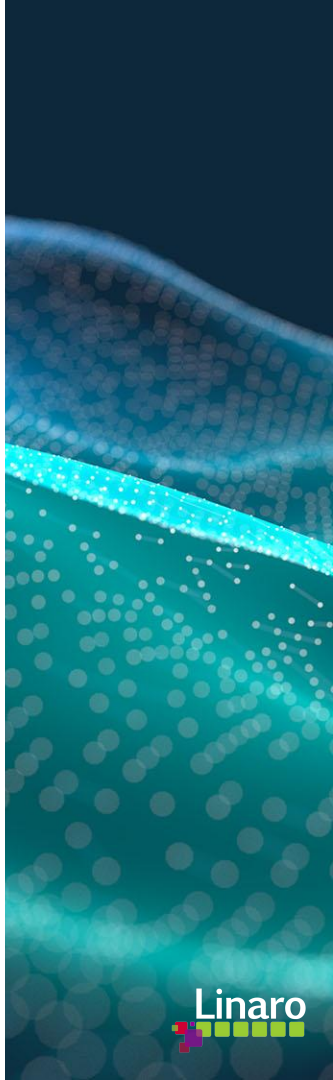
# Serialization in GPIOLIB

- If all that isn't enough: we have interrupt subsystem code calling GPIO code with spinlocks taken
- We also have pinctrl code we must call that takes mutexes



# Serialization in GPIOLIB

- A good mechanism has existed for years: SRCU
  - Read side locks can be taken from any context
  - Both sleeping and non-sleeping functions can be called with the SRCU read lock taken
- Conversion to using it took some time & effort, fixing several issues in all corners of the kernel but finally happened and is queued for linux v6.9
- GPIOLIB is now resistant to provider drivers being suddenly unbound and no longer crashes in these situations
- Still some issues to iron out with the interrupt subsystem glue code



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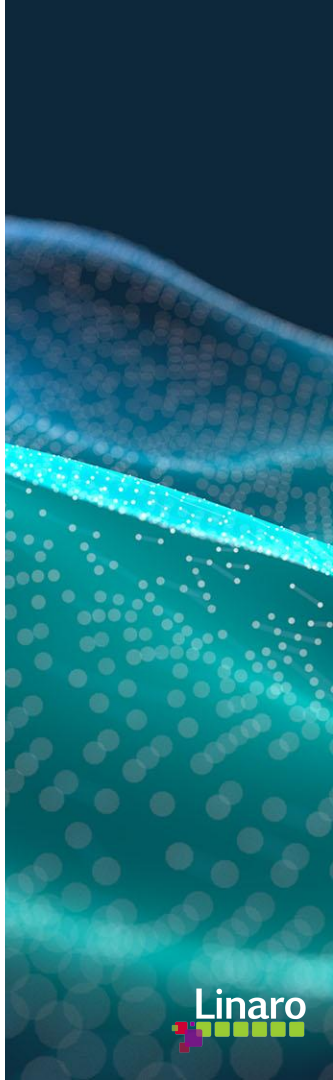

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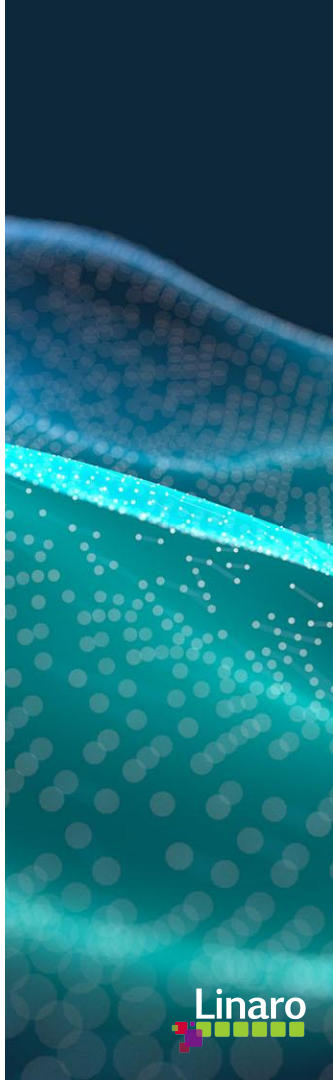

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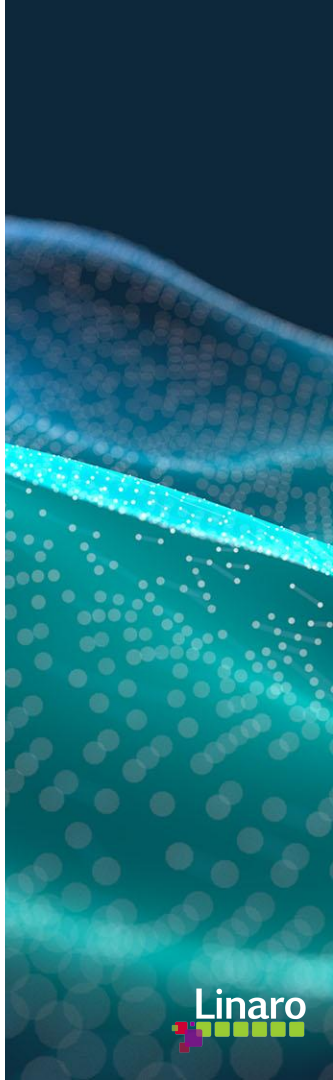

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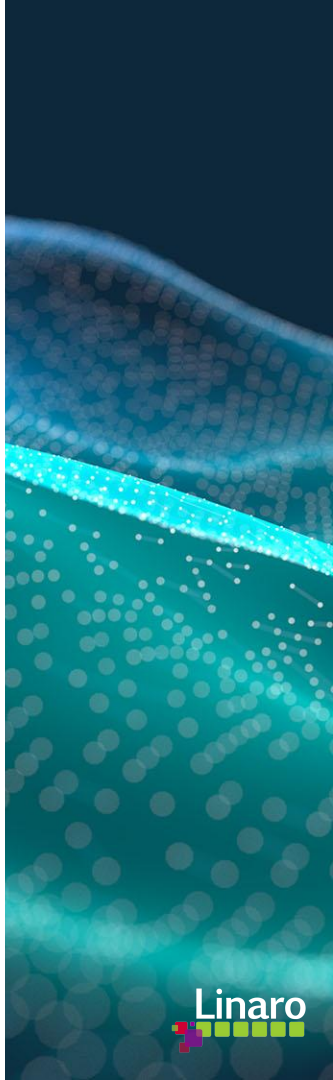

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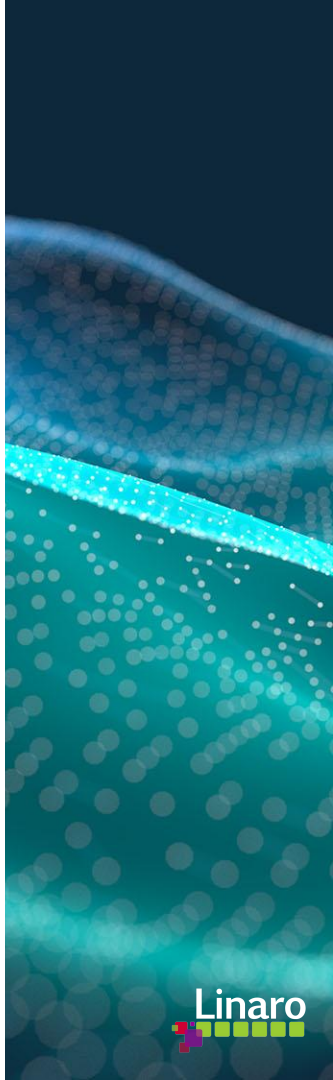

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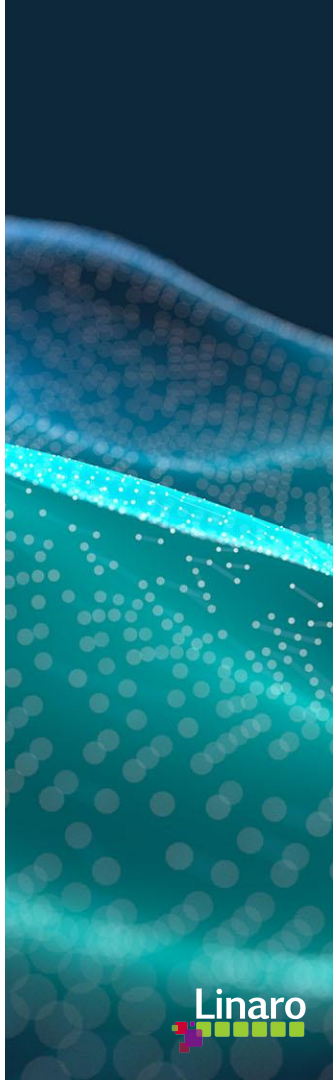

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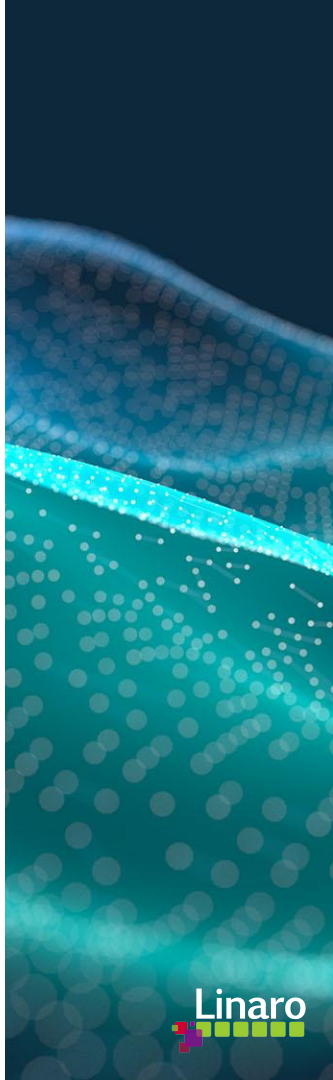

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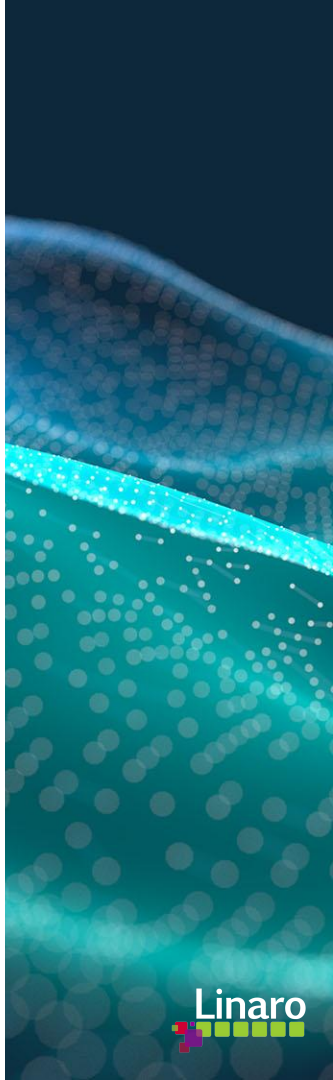
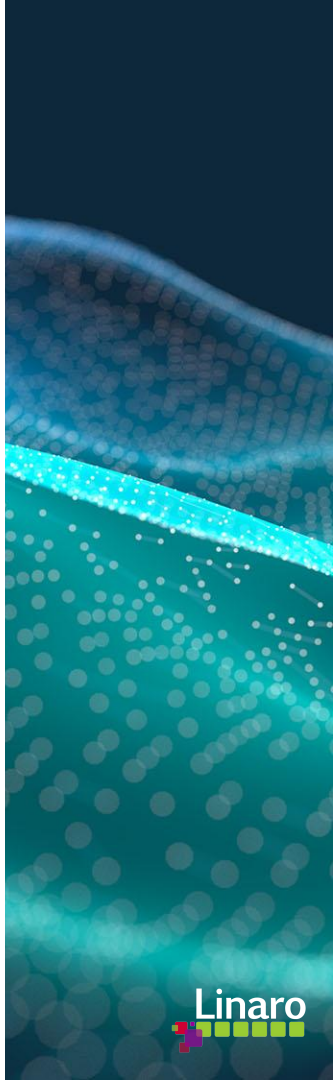
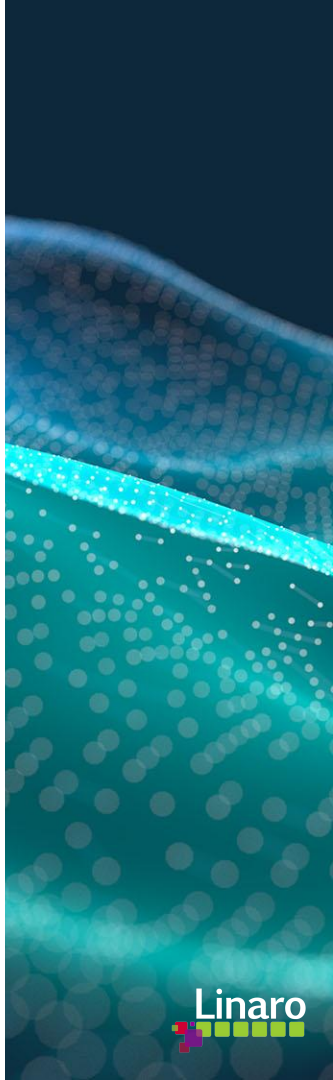


# GPIO user-space interface



# GPIO user-space interface

- The worst kind of technical debt
  - One that cannot be addressed if user-space doesn’t willingly comply



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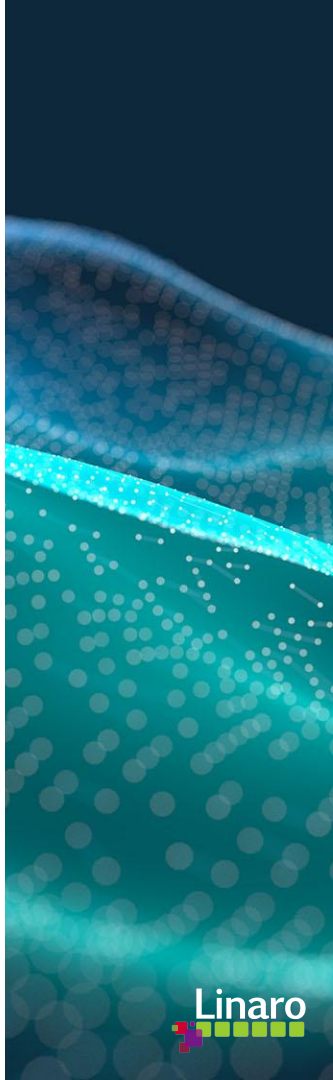

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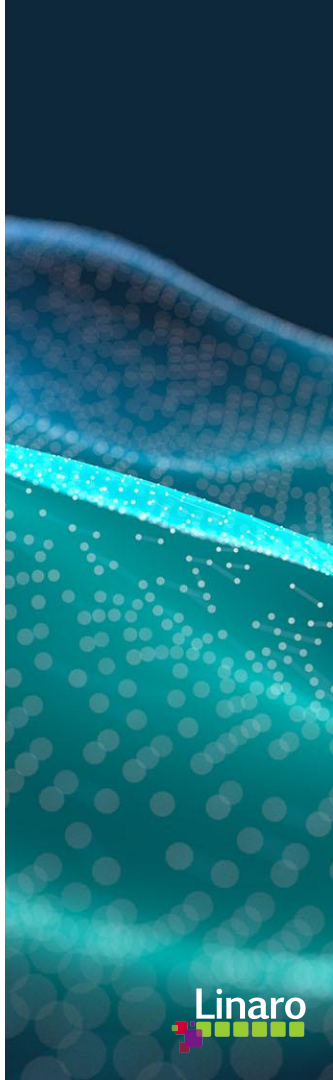

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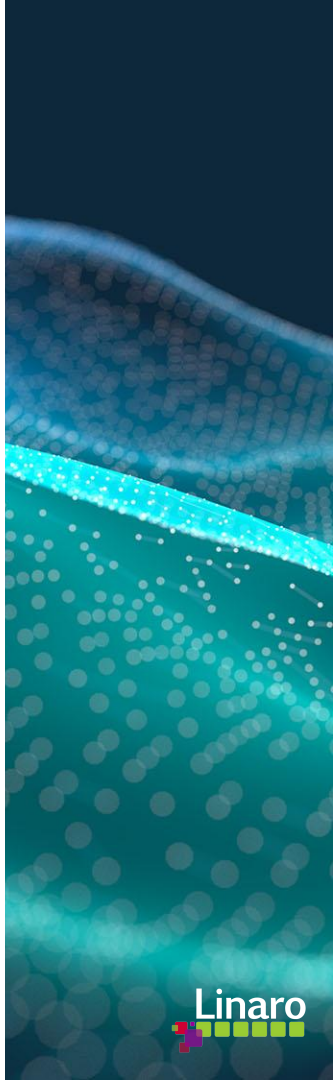
  - DBus API is in the works



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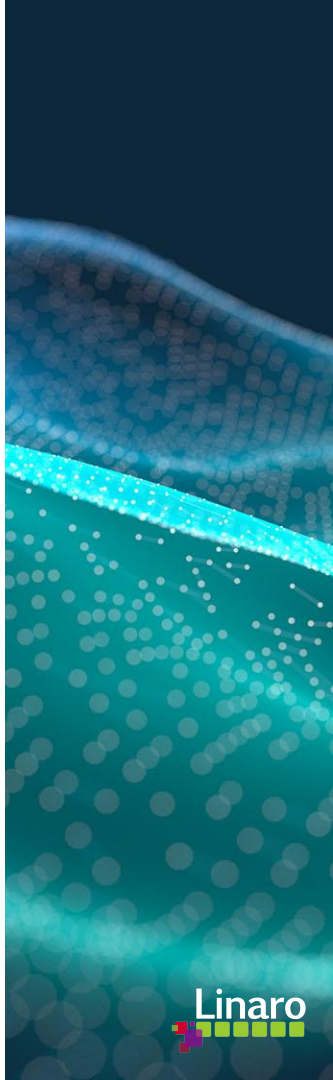
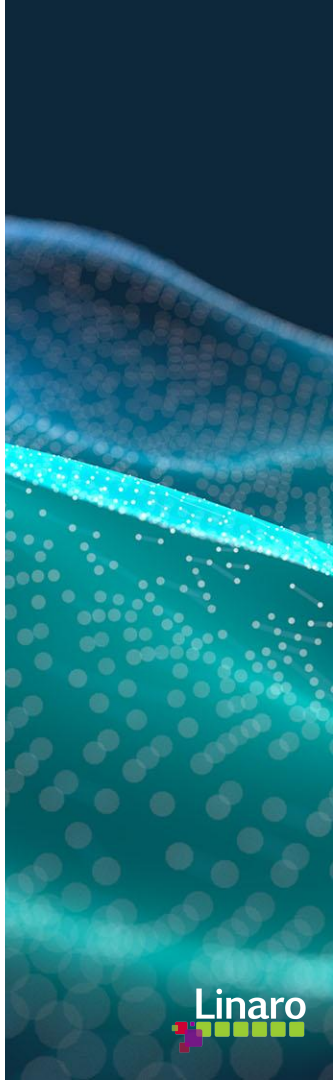
- From the kernel point of view we already have a good solution but we need more to make the user-space happy

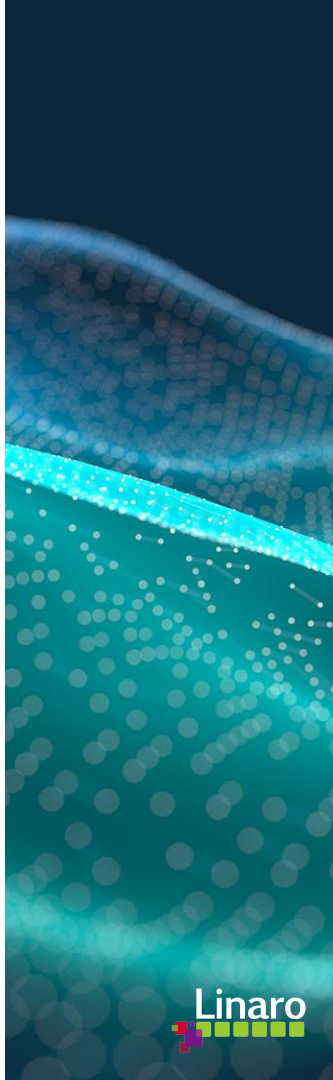


# Contain the quirks

- It’s a good idea to keep the quirk handling in a single place instead of having them scattered around

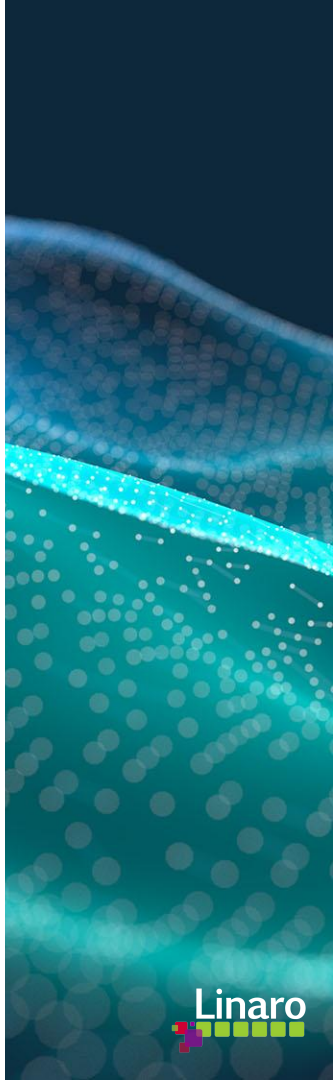


# Summary



# Summary

- Old subsystems acquire cruft over time



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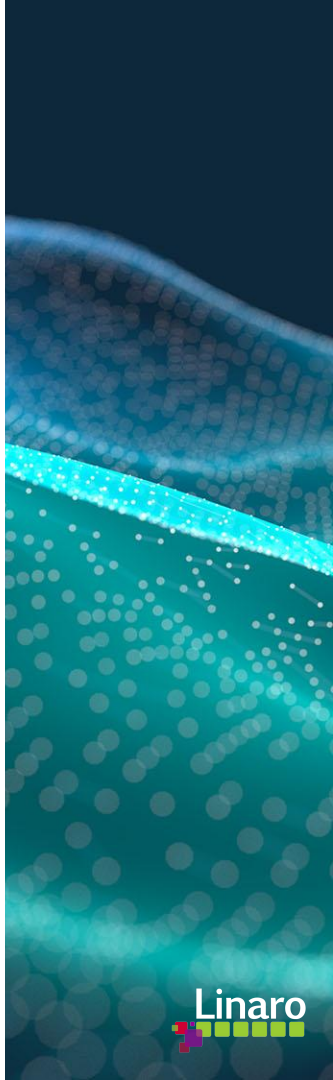

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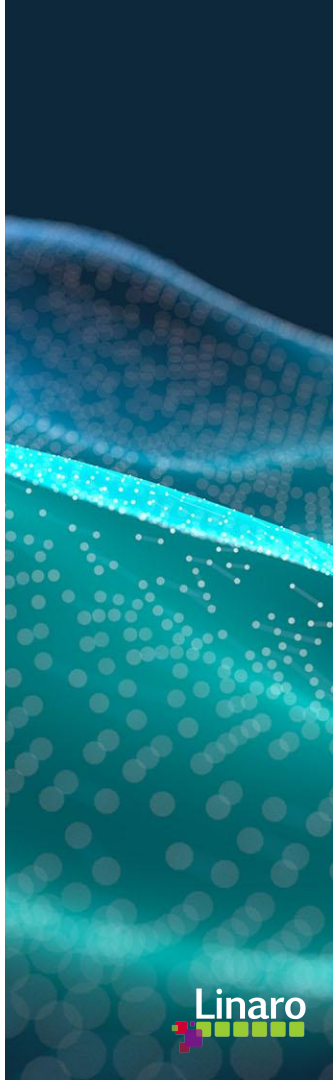
  - Because the best way to solve technical debt is to never allow it in the first place



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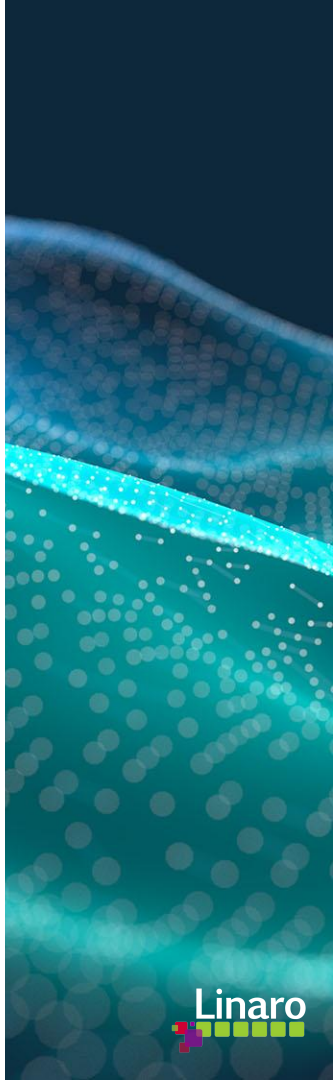
- It pays to be grumpy
  - Because the best way to solve technical debt is to never allow it in the first place
- We could use some kind of a deprecation mechanism
  - Checkpatch?
  - Coccinelle?
  - Compiler attributes



# Thank you

## Q & A

Visit www.linaro.org
Reach out to me at bartosz.golaszewski@linaro.org